

# **The 2003 M6.5 San Simeon and 2004 M6.0 Parkfield Earthquakes in Central California**

Jeanne Hardebeck  
US Geological Survey

With thanks to:

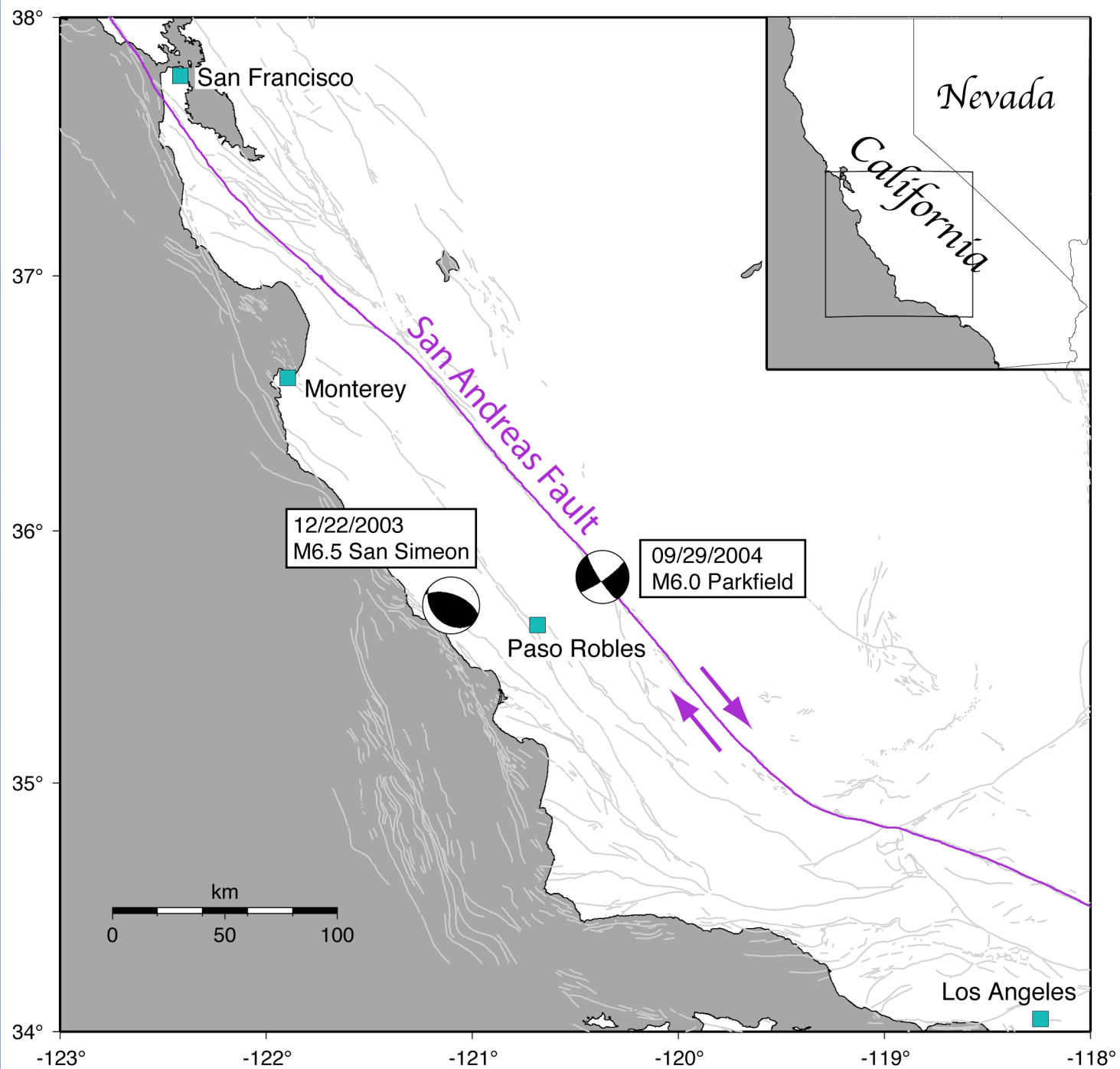
Andrew Michael, Robert Simpson, John Tinsley; USGS.

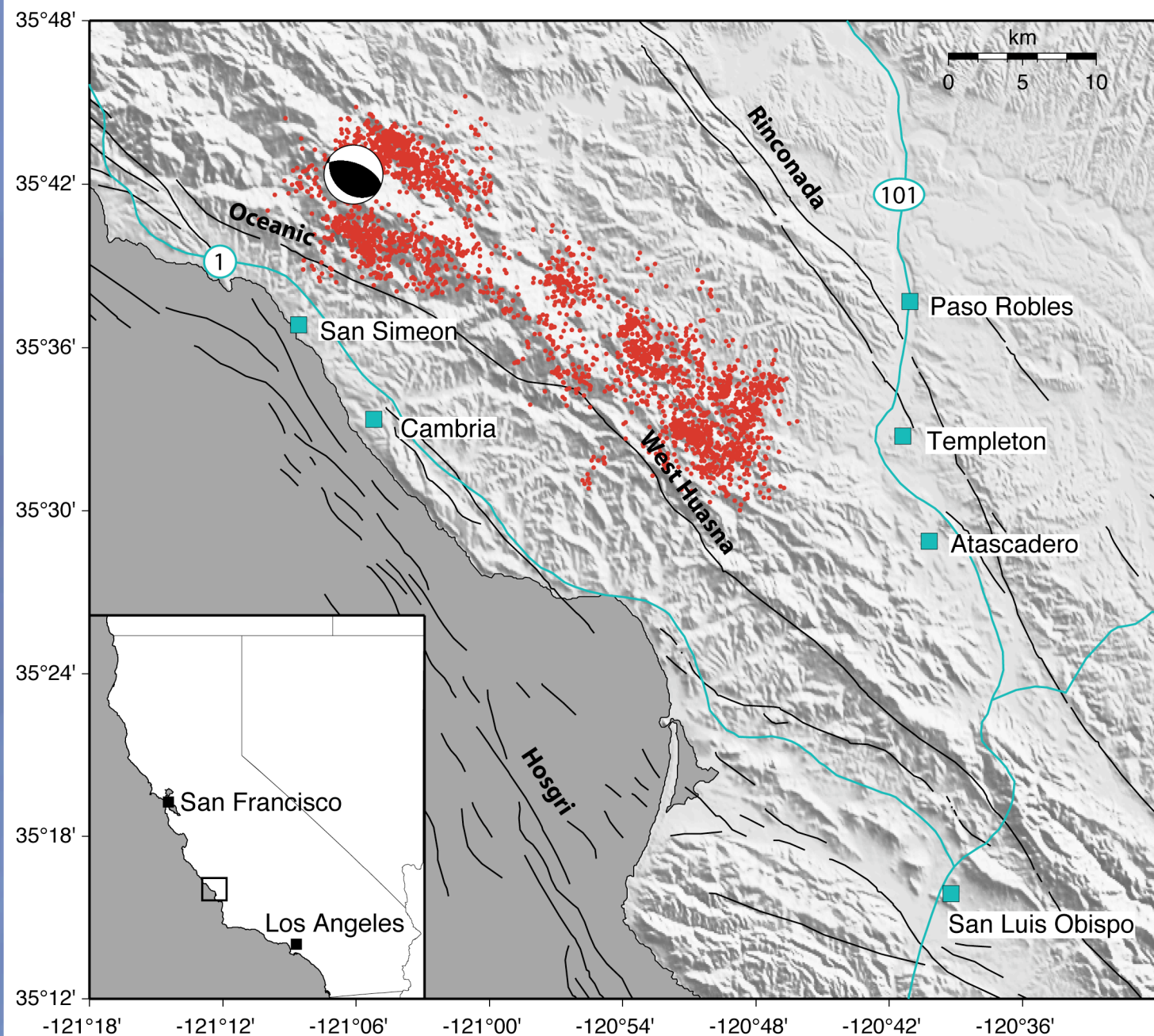
Doug Dreger; University of California, Berkeley.

Chen Ji; Caltech.

Vladimir Graizer; California Geological Survey.

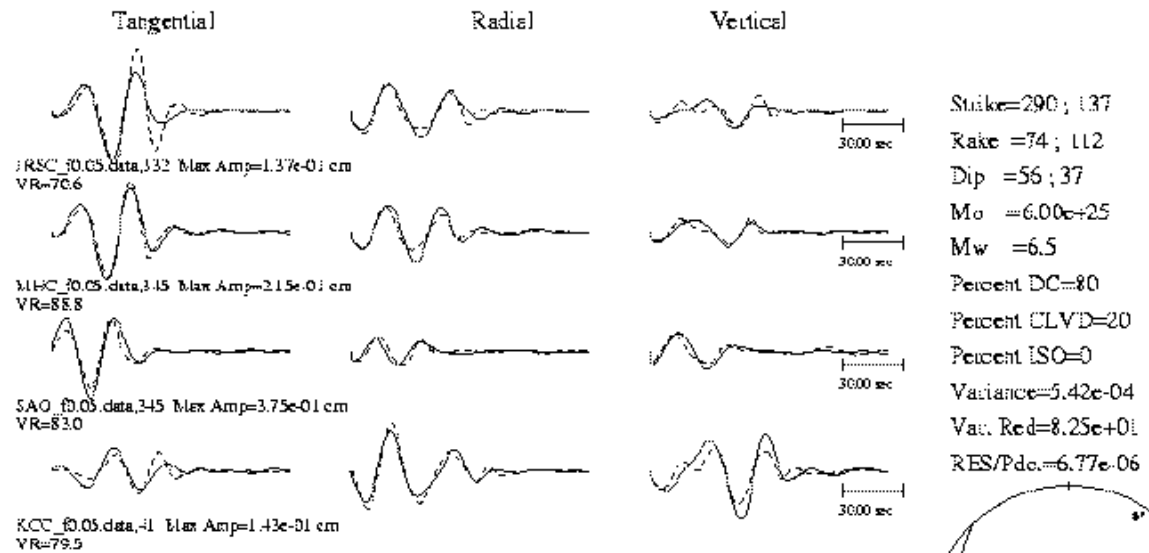
Rakesh Goel; California Polytechnic University, San Luis Obispo.



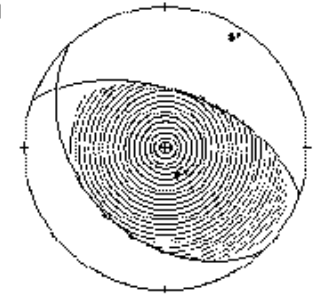


## Thrust Event:

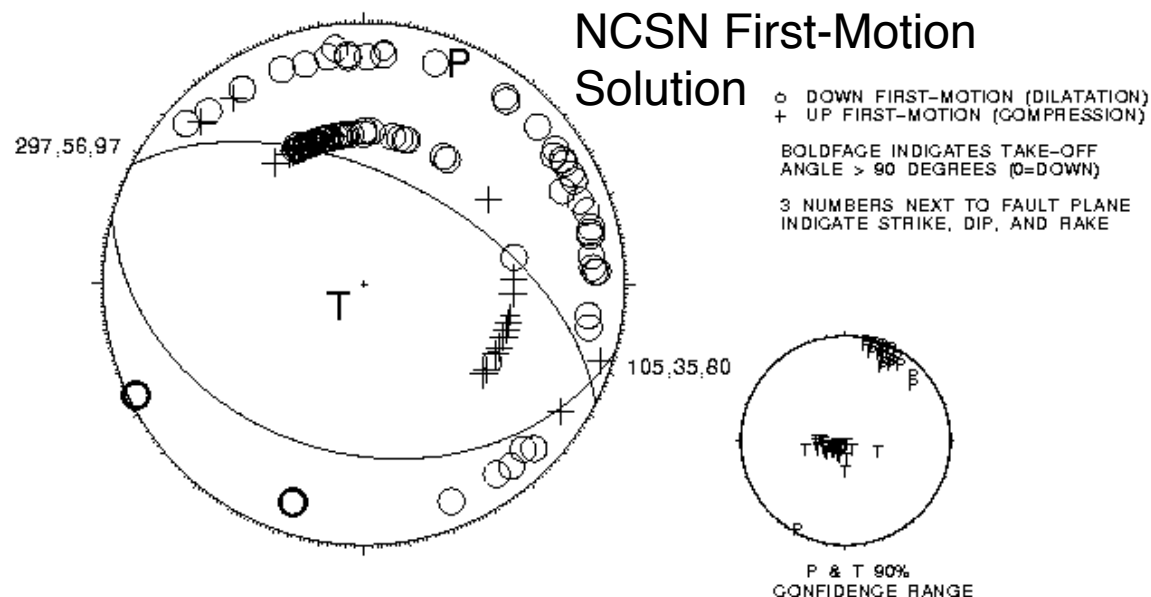
- NW-SE striking fault plane
- dipping steeply ( $\sim 56^\circ$ ) to NE, or shallowly ( $\sim 36^\circ$ ) to SW



## Berkeley Moment Tensor Solution

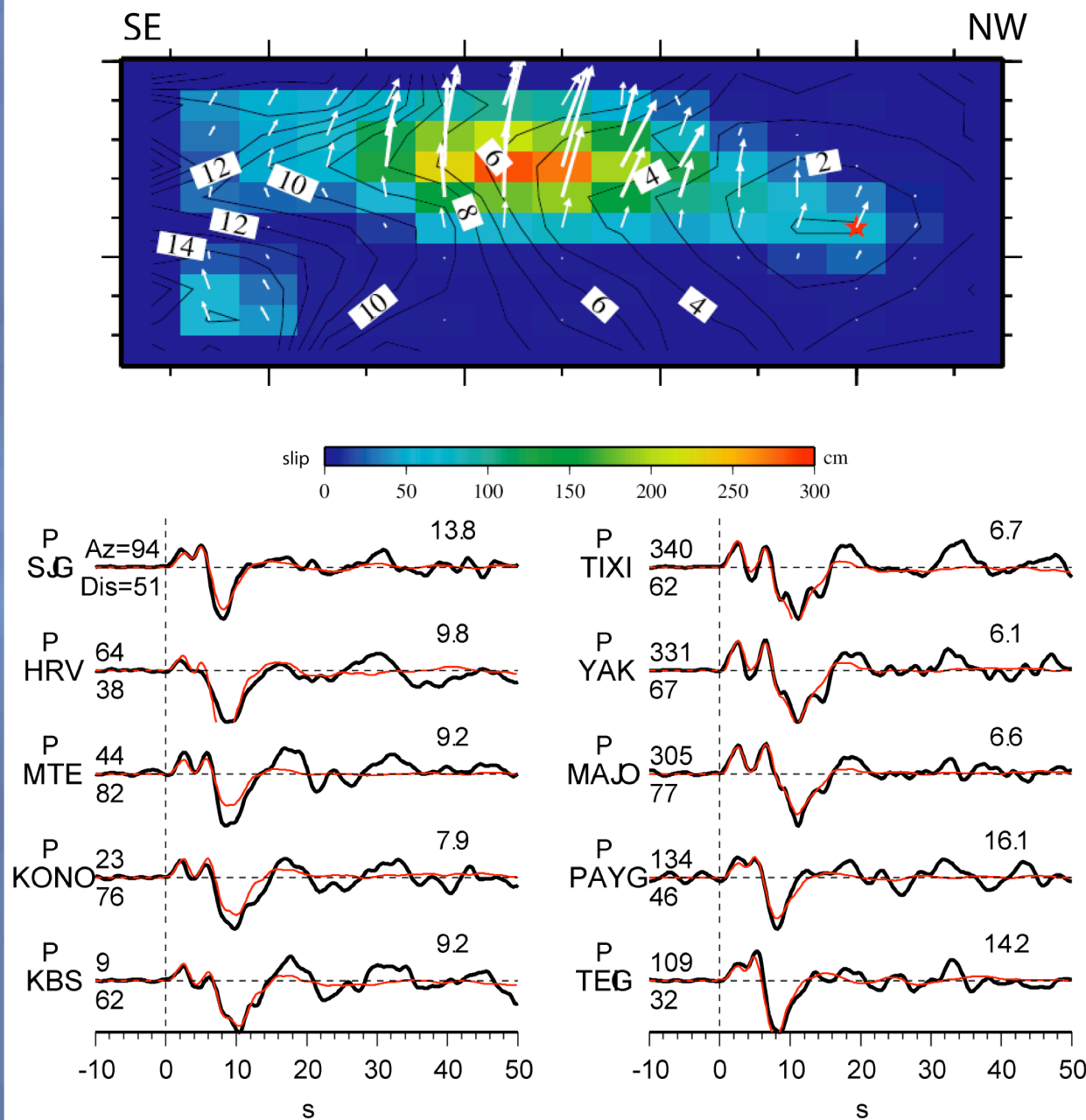


## NCSN First-Motion Solution



From: Doug Dreger & NCSN.

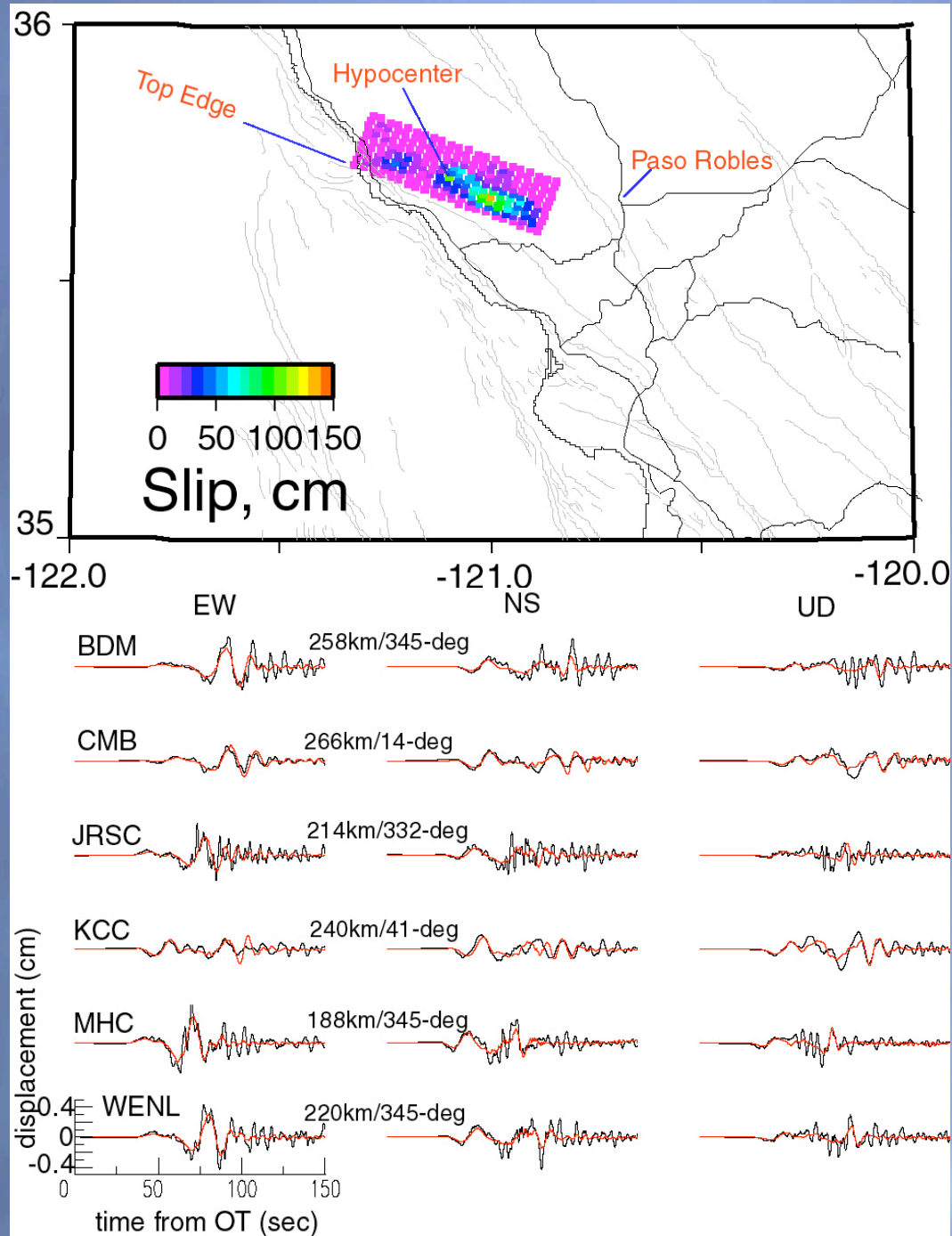




## Finite Source Model

- Teleseismic data (IRIS), P waves.
- Unilateral to SE.
- Simple pattern: with main slip patch ~15 km SE of hypocenter.

From: Chen Ji.



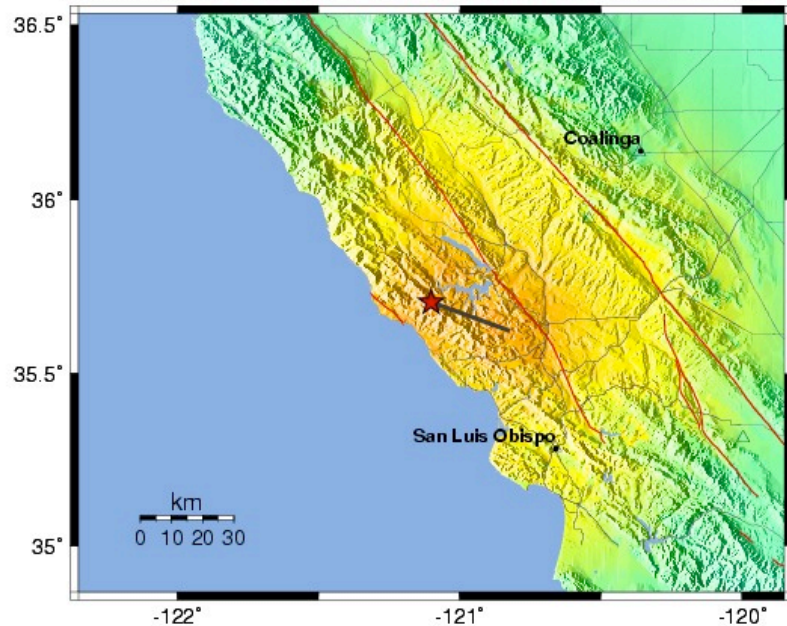
## Finite Source Model

- Regional broadband data (BDSN).
- Unilateral to SE.
- Simple pattern: with main slip patch ~15 km SE of hypocenter.

From: Doug Dreger.

# Unilateral rupture consistent with asymmetry in peak ground motion.

CISN Rapid Instrumental Intensity Map Epicenter: 11 km NE of San Simeon, CA  
Mon Dec 22, 2003 11:15:56 AM PST M 6.5 N35.71 W121.10 Depth: 7.6km ID:40148755

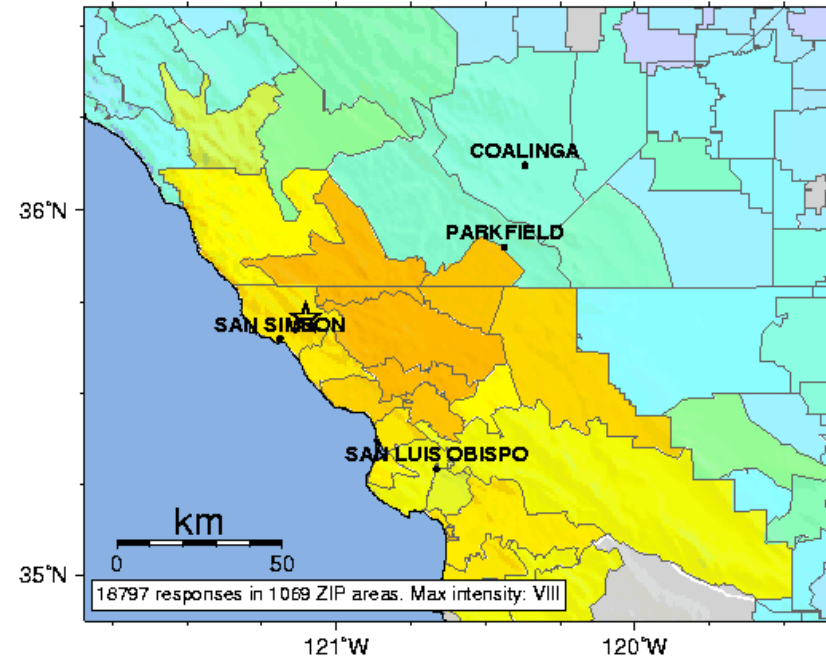


PROCESSED: Mon Dec 22, 2003 09:11:26 PM PST.

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC (%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

ShakeMap with line source.

Community Internet Intensity Map (11 miles N of Cambria, CA)  
ID:40148755 11:15:56 PST DEC 22 2003 Mag=6.5 Latitude=N35.71 Longitude=W121.10



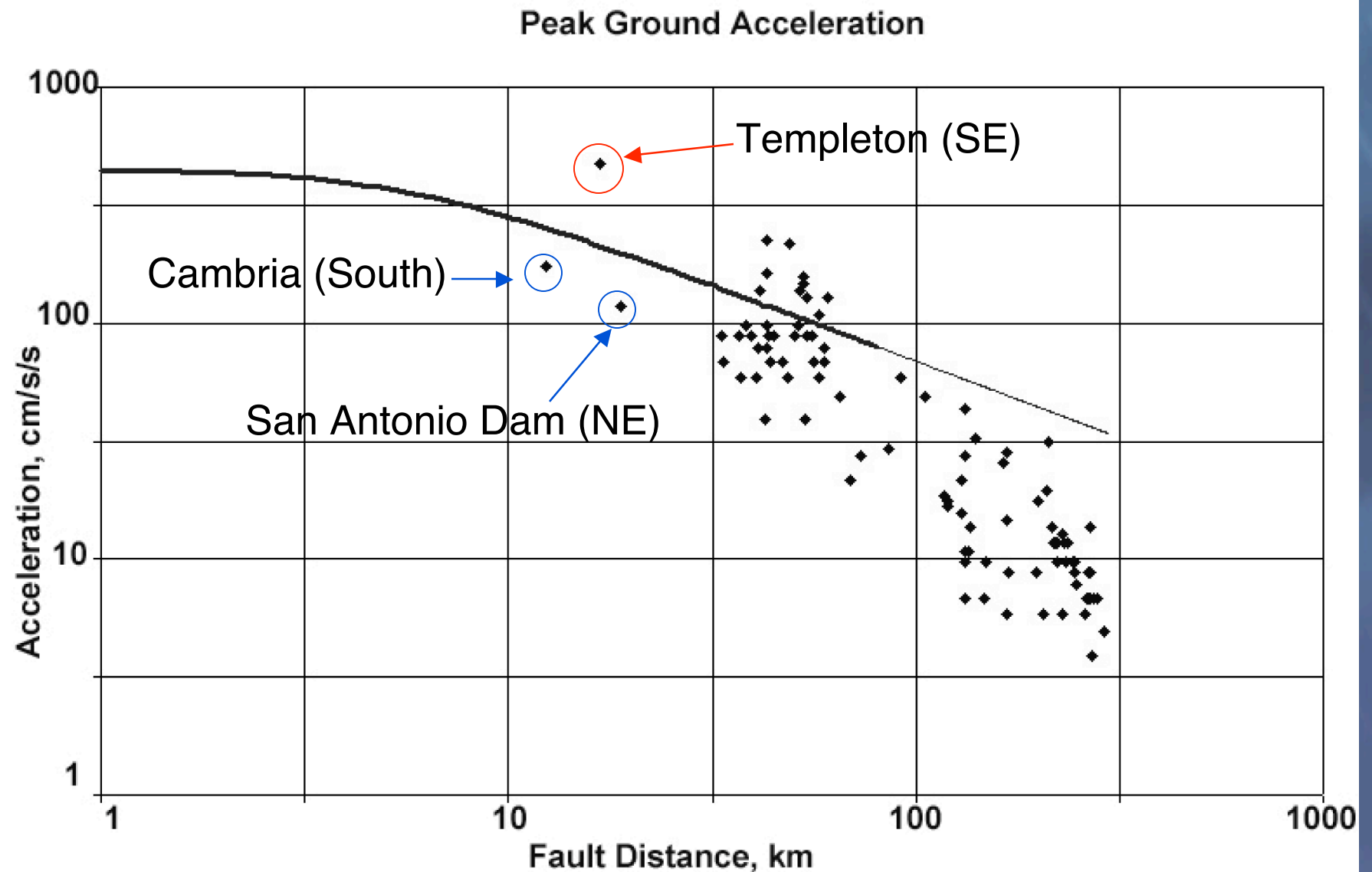
Map last updated on Sun Jan 25 10:37:56 2004

INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

Community Internet Intensity Map.

From: Doug Dreger.

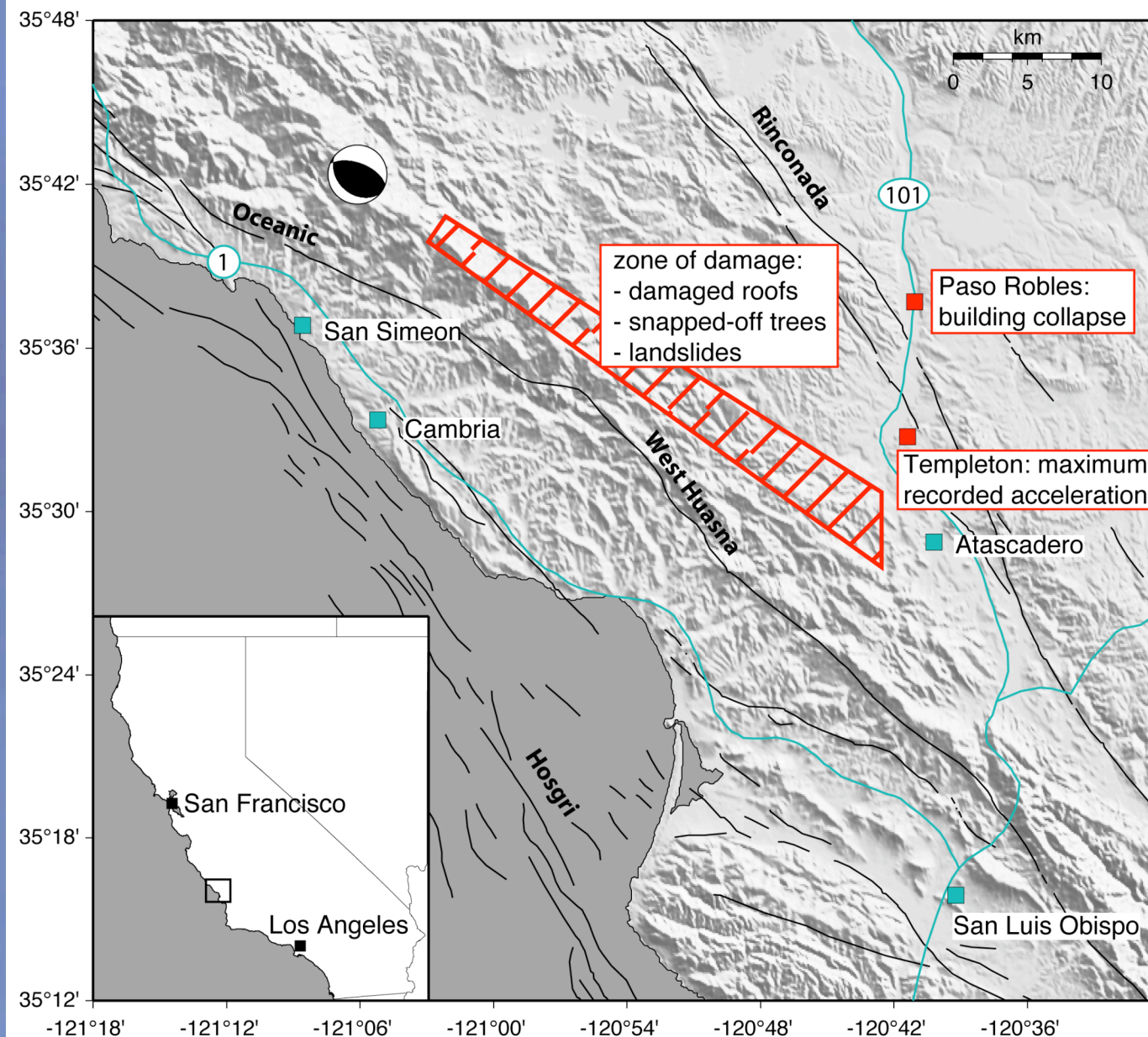
Additional asymmetry in ground motion from SE directivity:



From: Vladimir Graizer.

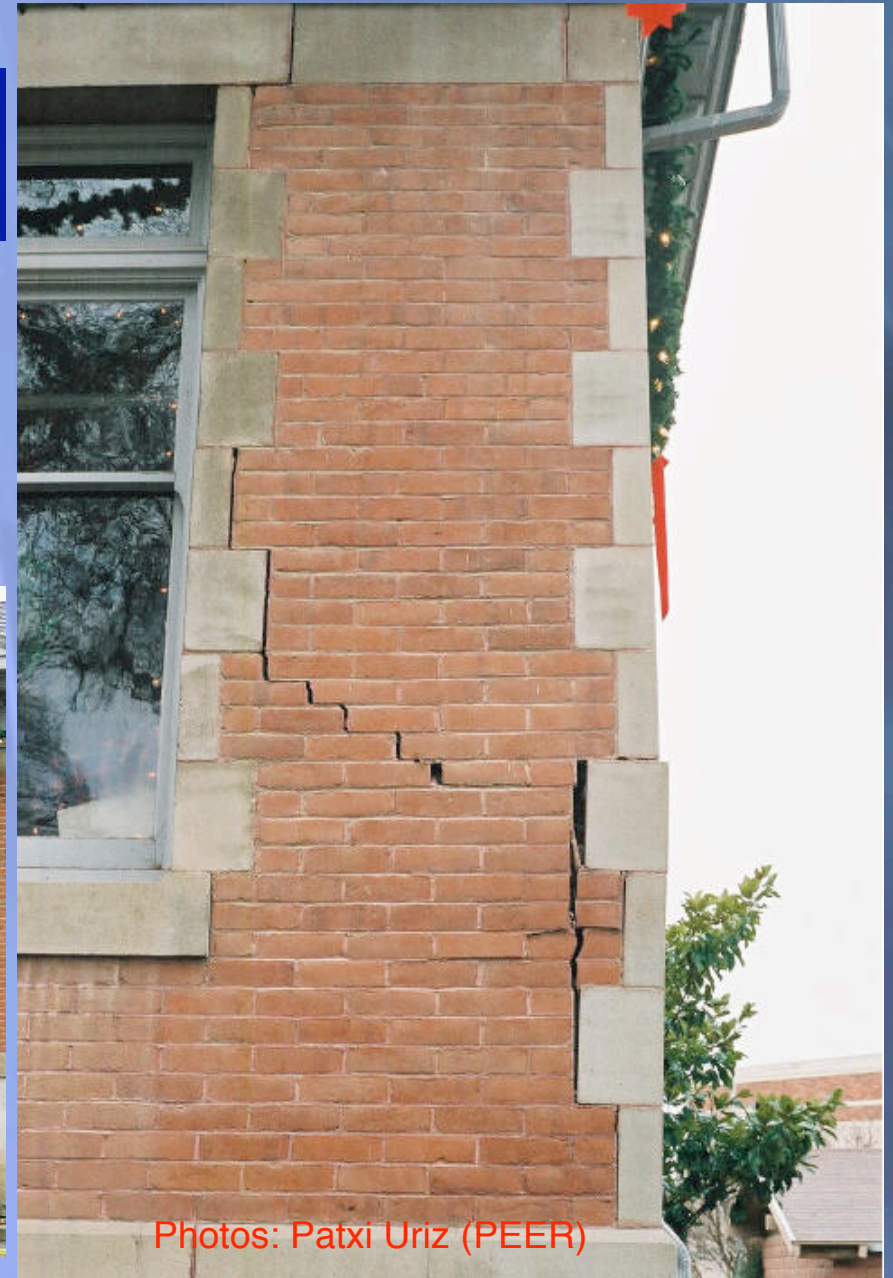


## Directivity Apparent in Distribution of Damage





## Failure of unreinforced masonry (brick) buildings in Paso Robles.



Photos: Patxi Uriz (PEER)



## Failure of unreinforced masonry buildings in Paso Robles: The Acorn Building.

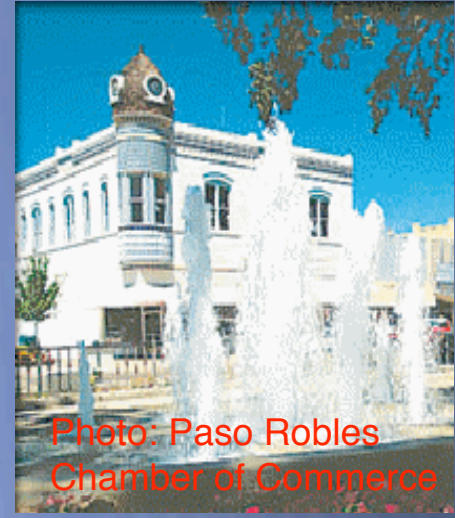


Photo: Paso Robles  
Chamber of Commerce



Photo: Rakesh Goel



Photo: Junichi Sakai (PEER)



## Retrofit buildings in Paso Robles performed well.



Photo: Janise Rodgers

- Recently retrofit.
- Less than a block from the collapsed Acorn building.
- No structural damage.





Photo: CGS



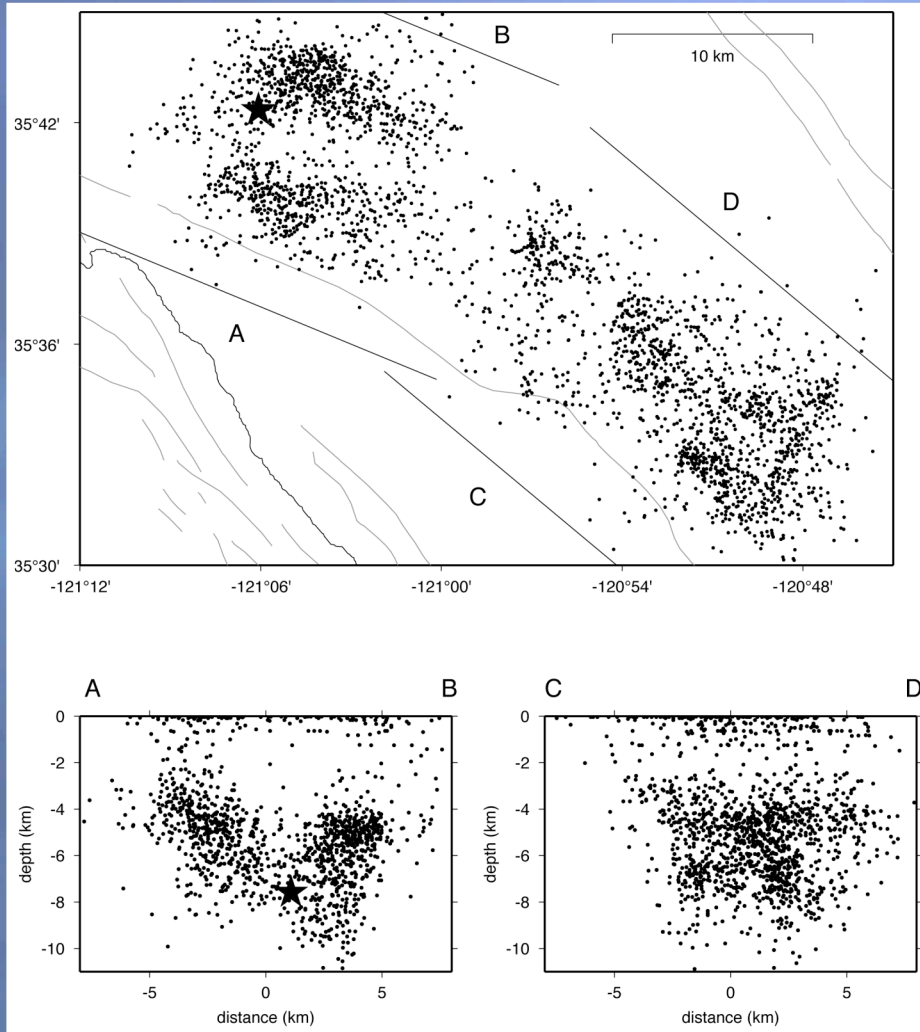
Photo: Rakesh Goel



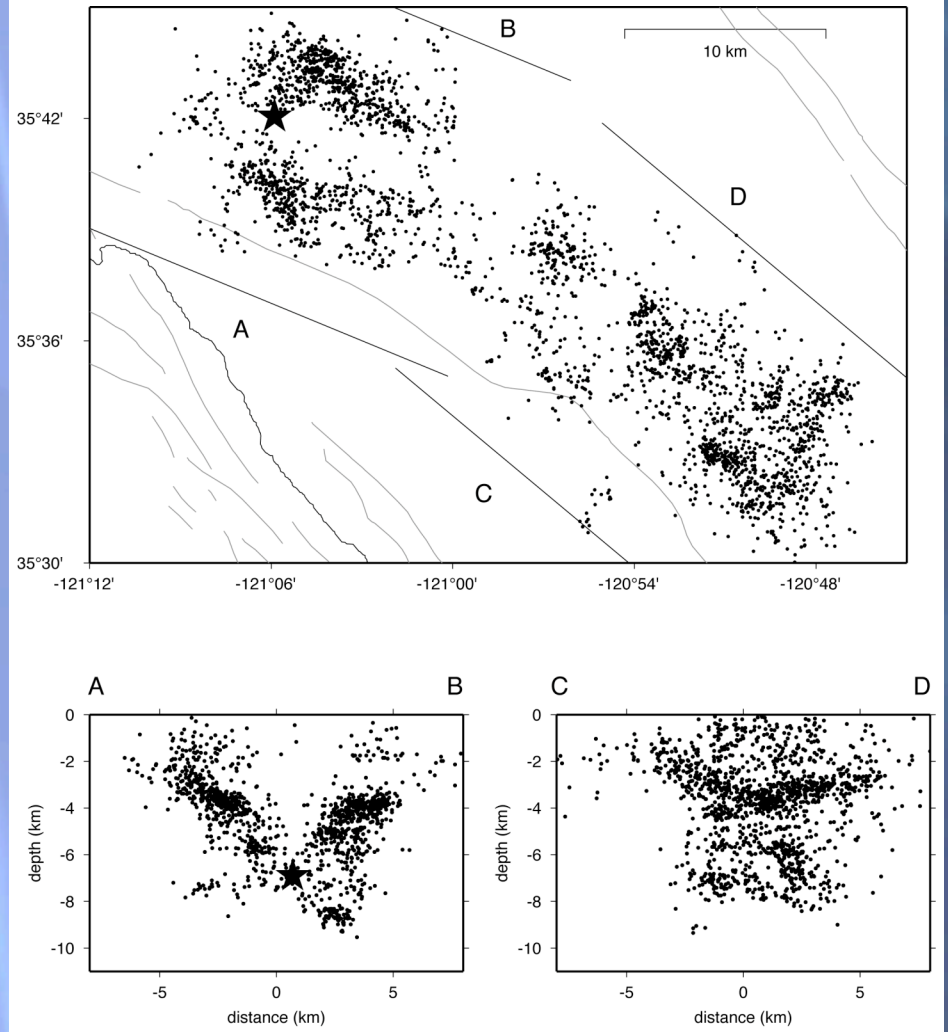
Photo: Junichi Sakai (PEER)

- Sulfur hot springs (Paso Robles City Hall parking lot)
- Temperature: 111°F / 44°C
  - Flow rate: 1000 gallons/min / 3800 liter/min
  - Site of former hot spring resort.

## Catalog Locations:

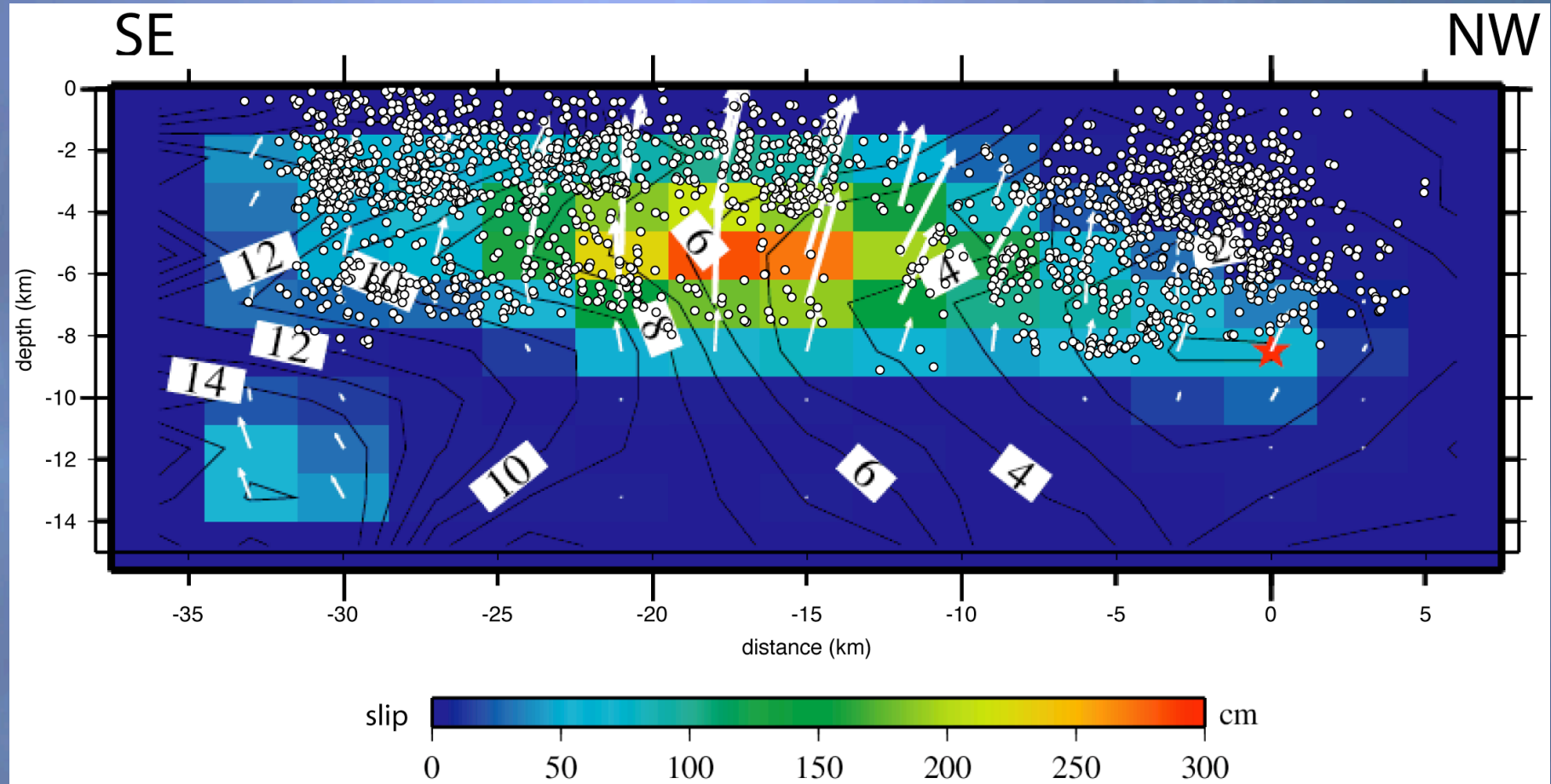


## Double-difference relocations:



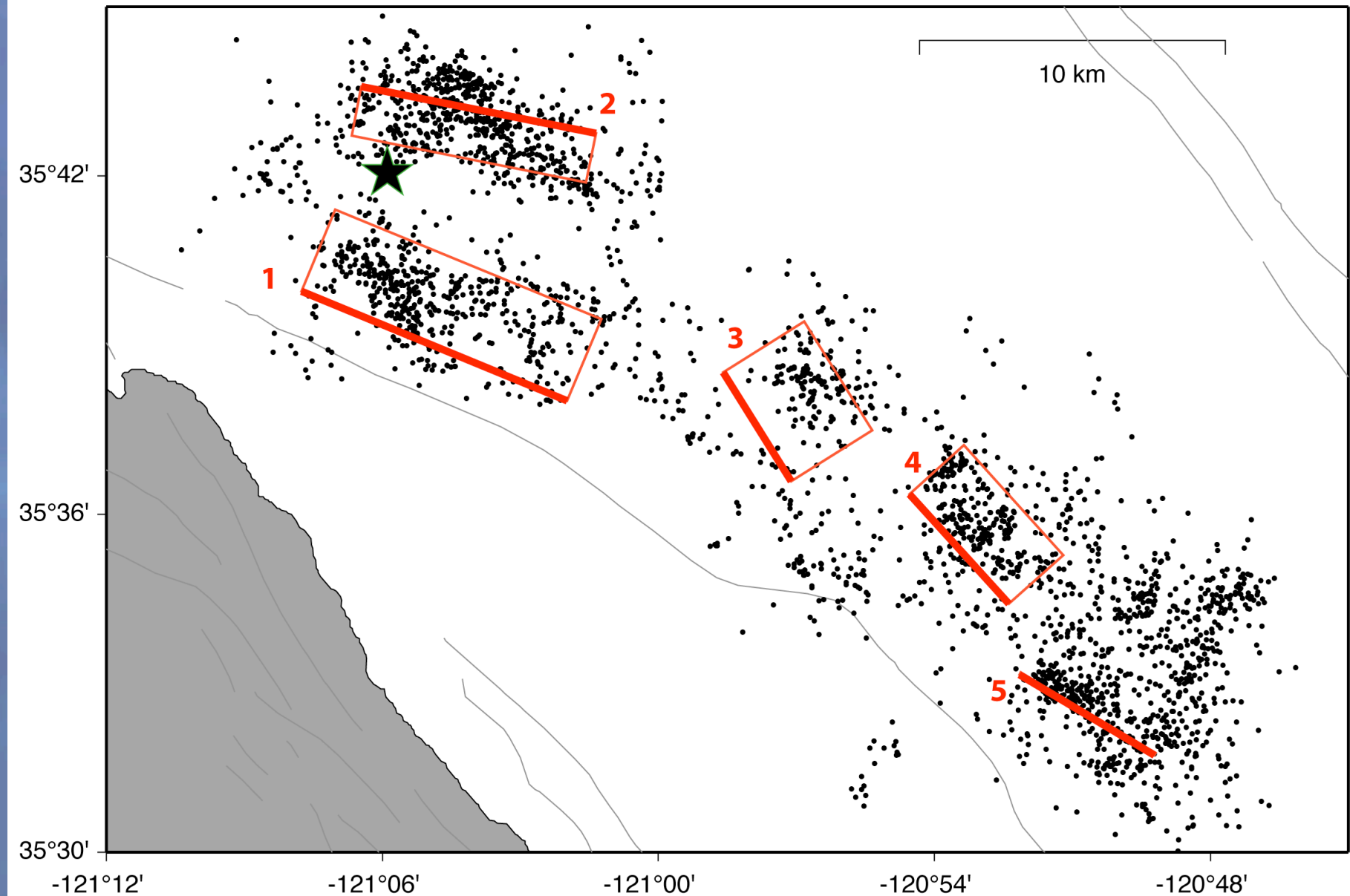
Based on phase data from the NCSN

## Aftershocks surround main slip patch:

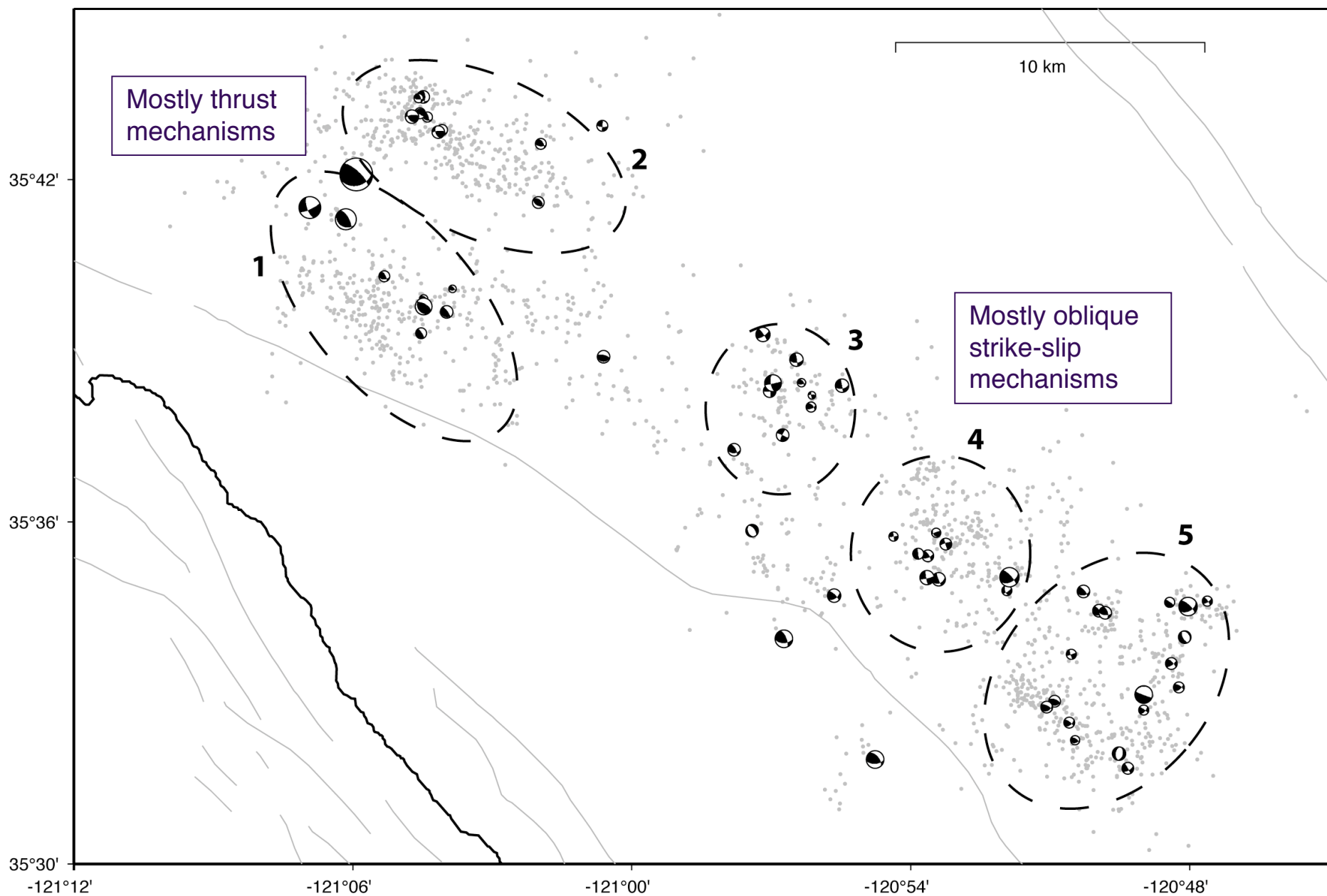


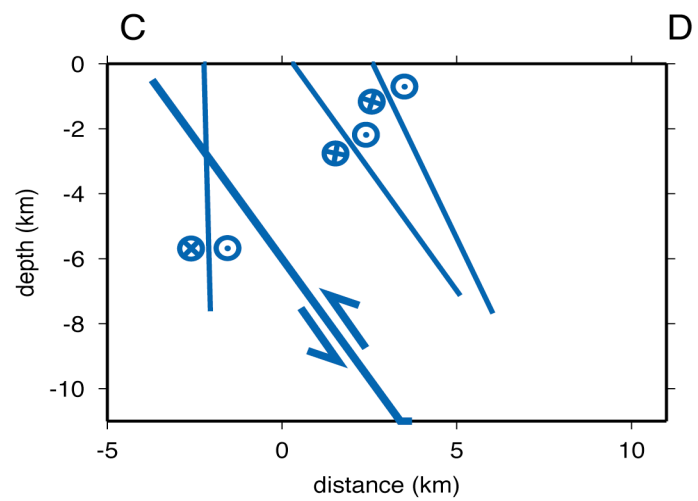
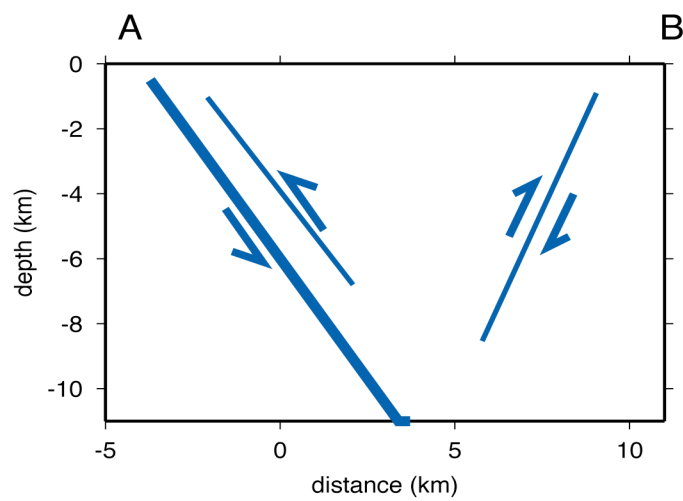
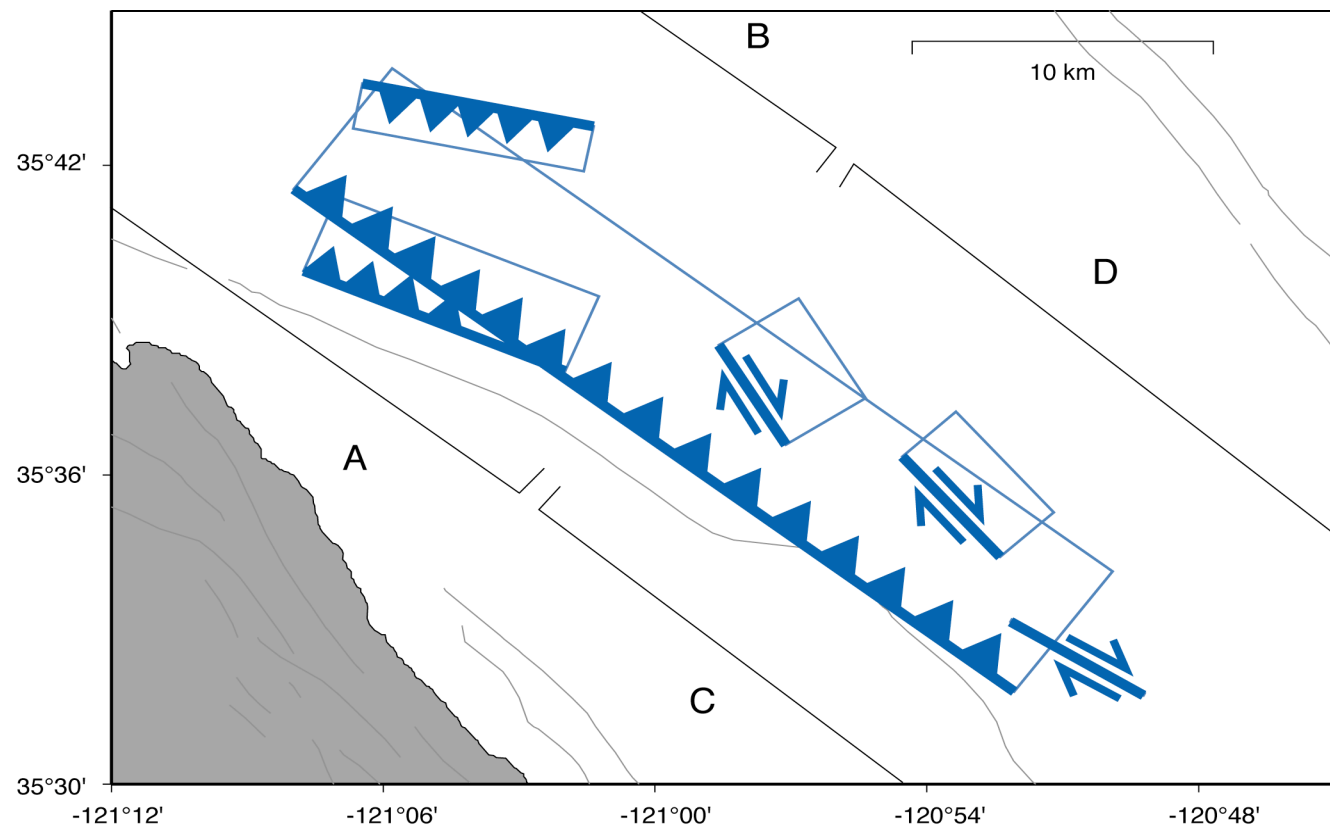
Slip model from Chen Ji



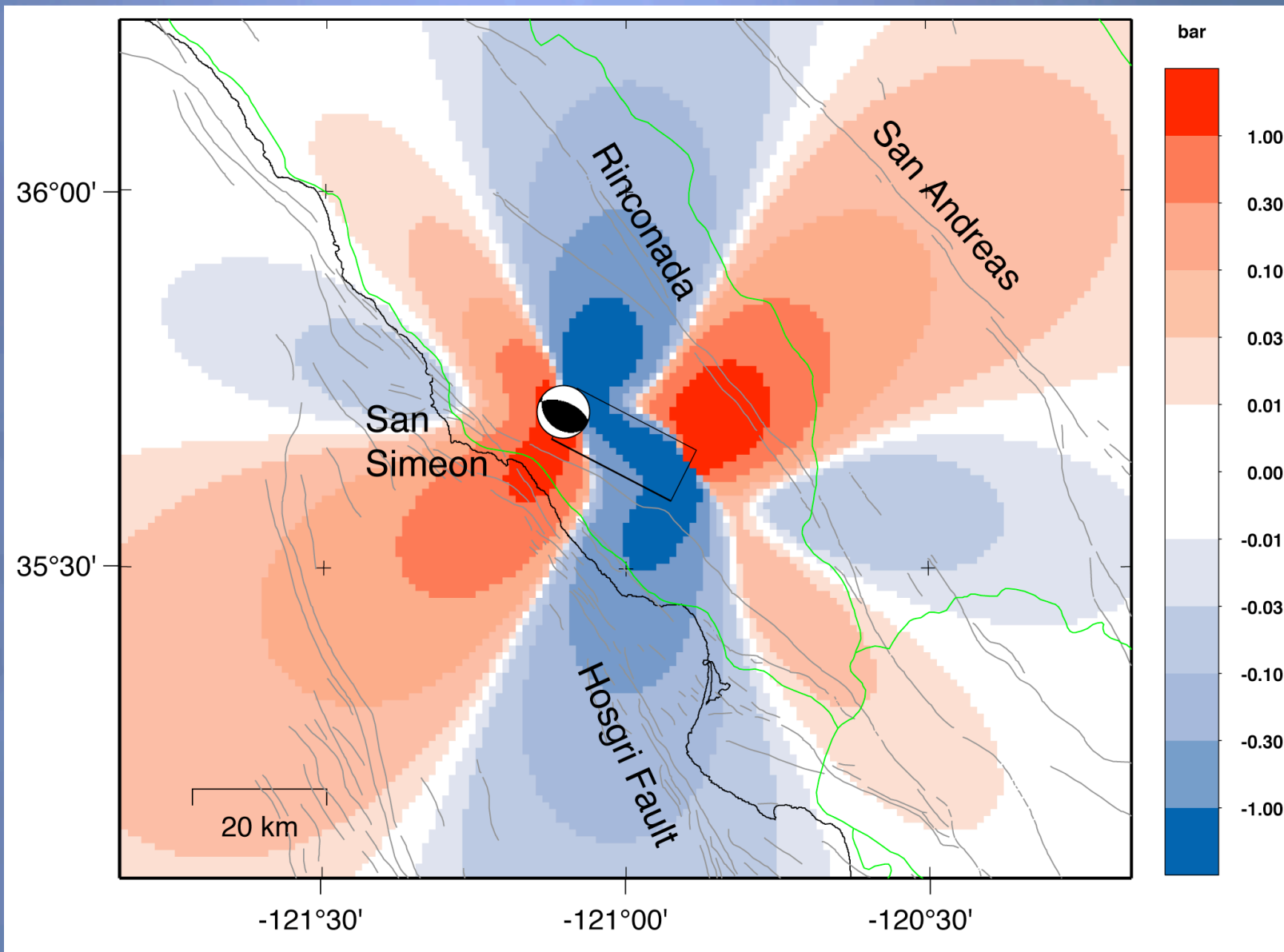






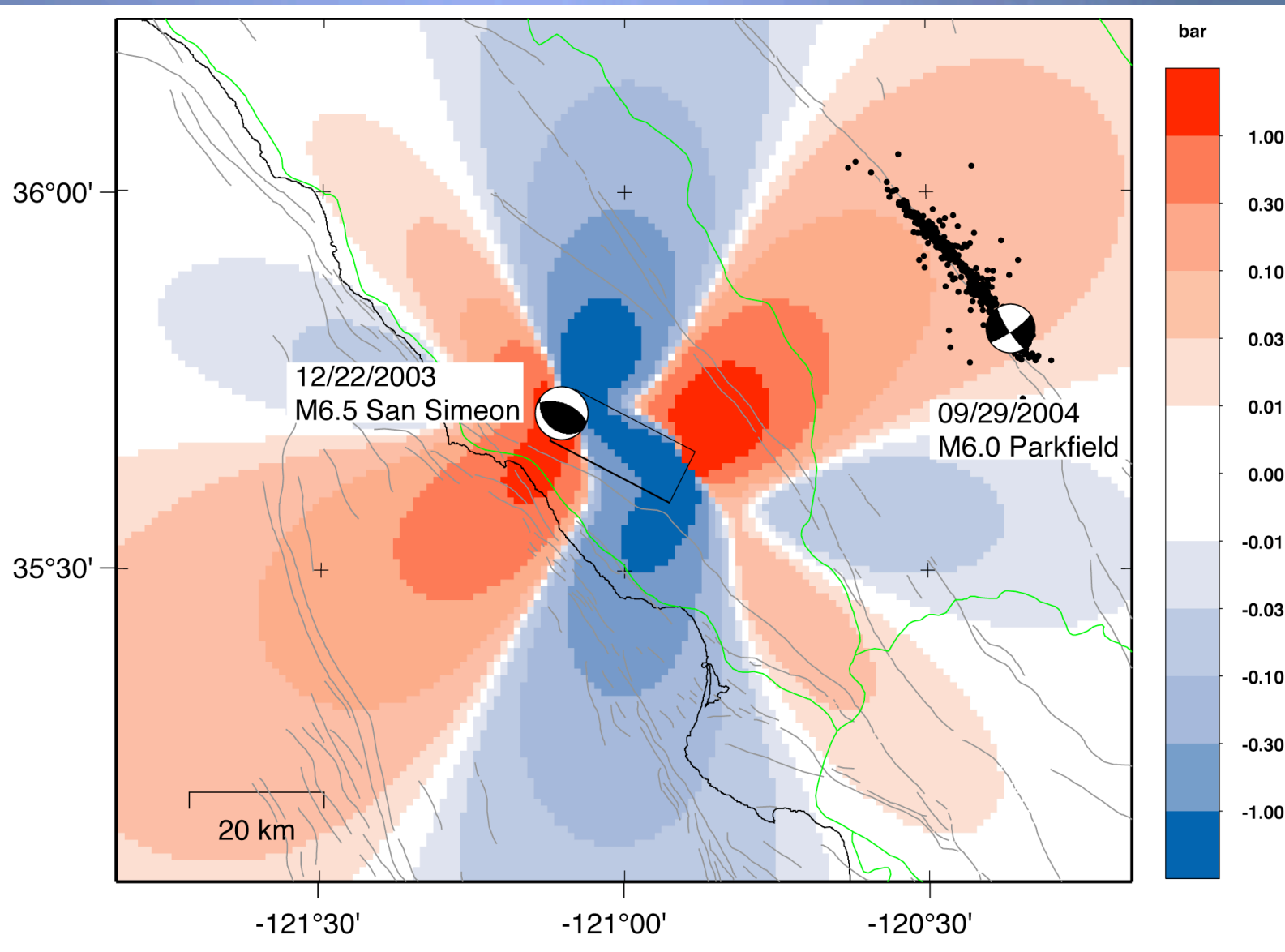


## Static stress changes due to San Simeon mainshock.



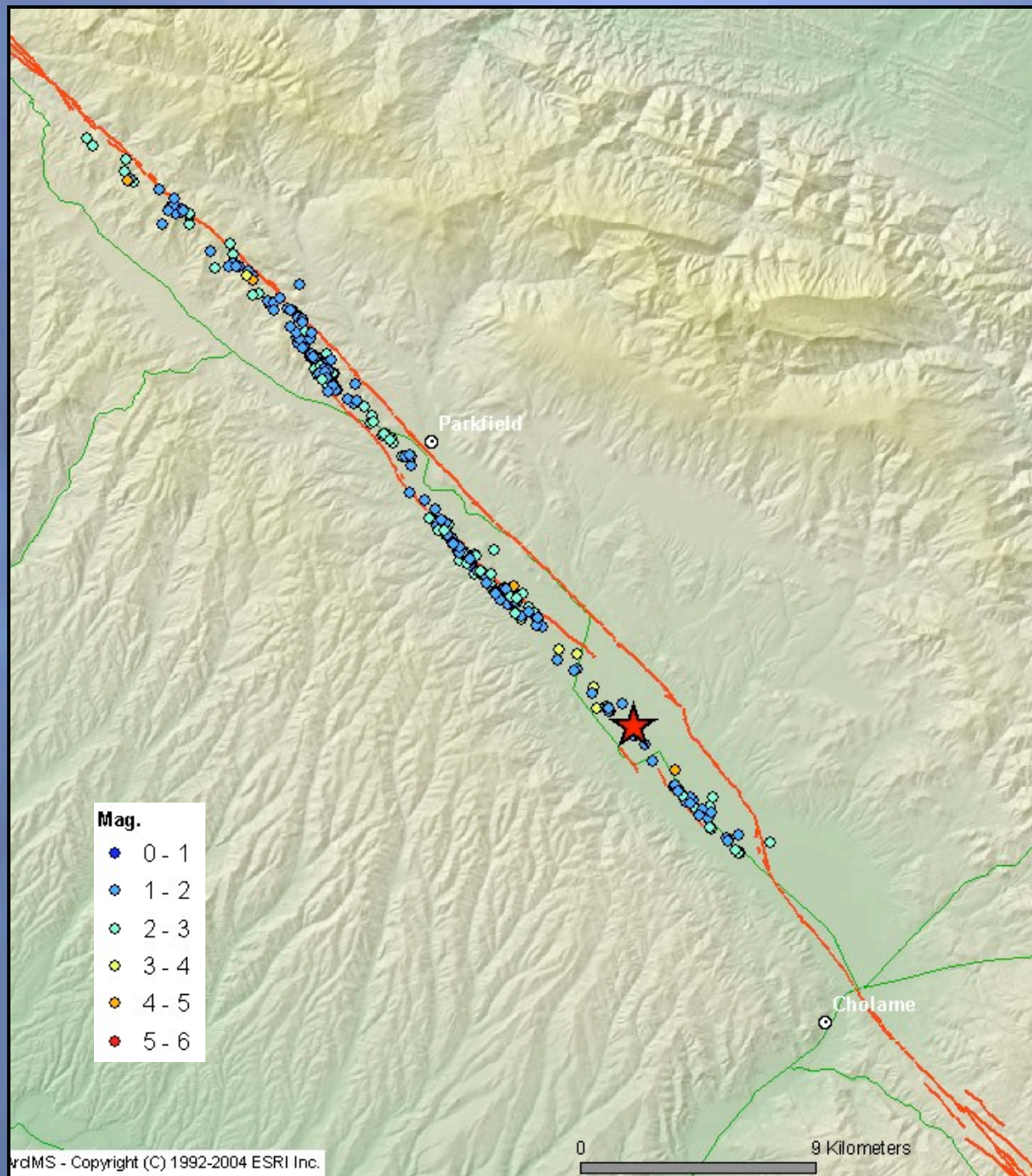
From: Bob Simpson

Parkfield M6.0 occurs ~9 months later,  $\leq 0.1$  bar stress change.



From: Bob Simpson (stress)  
NCSN (earthquakes)





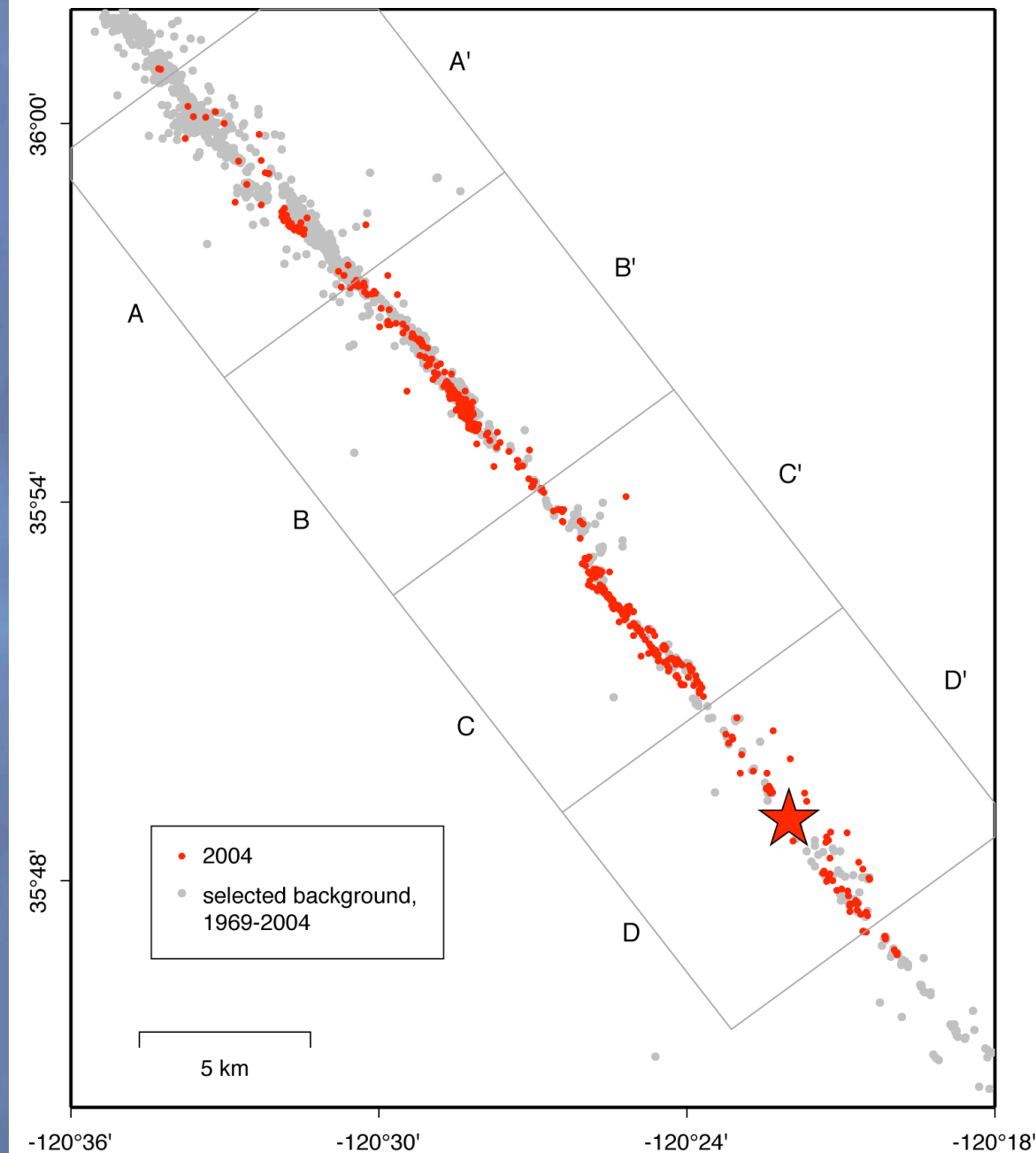
## Parkfield Aftershock relocation:

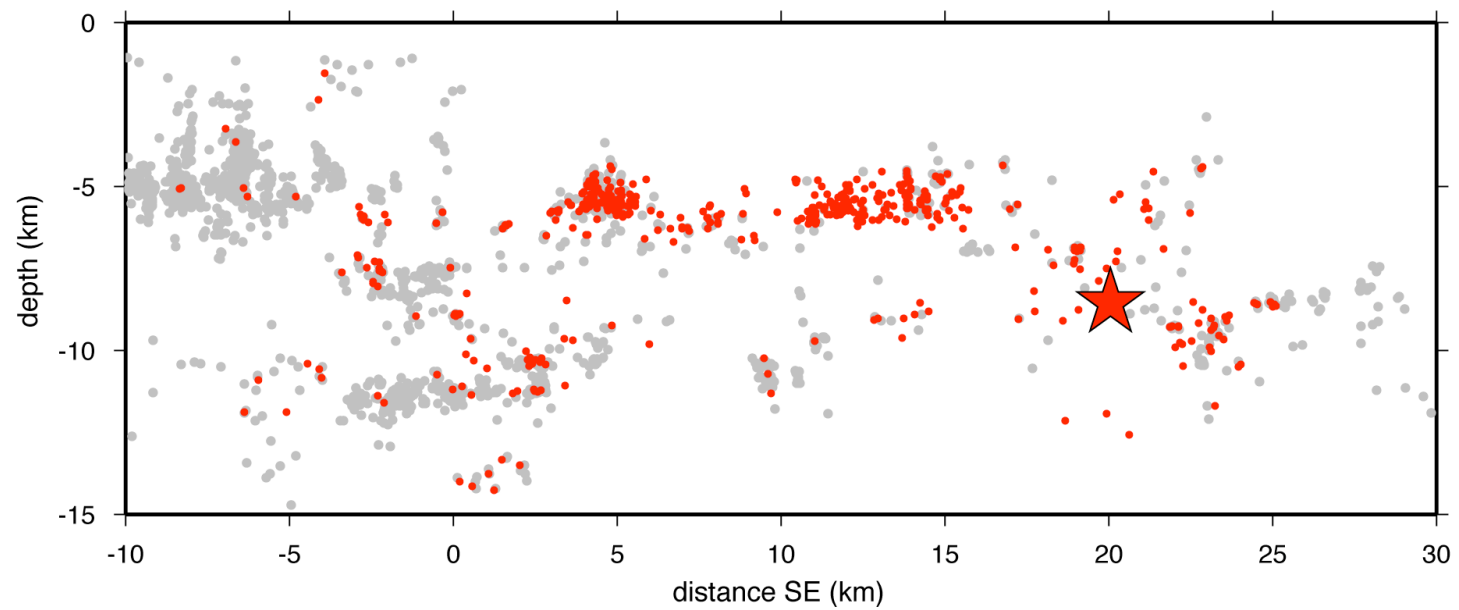
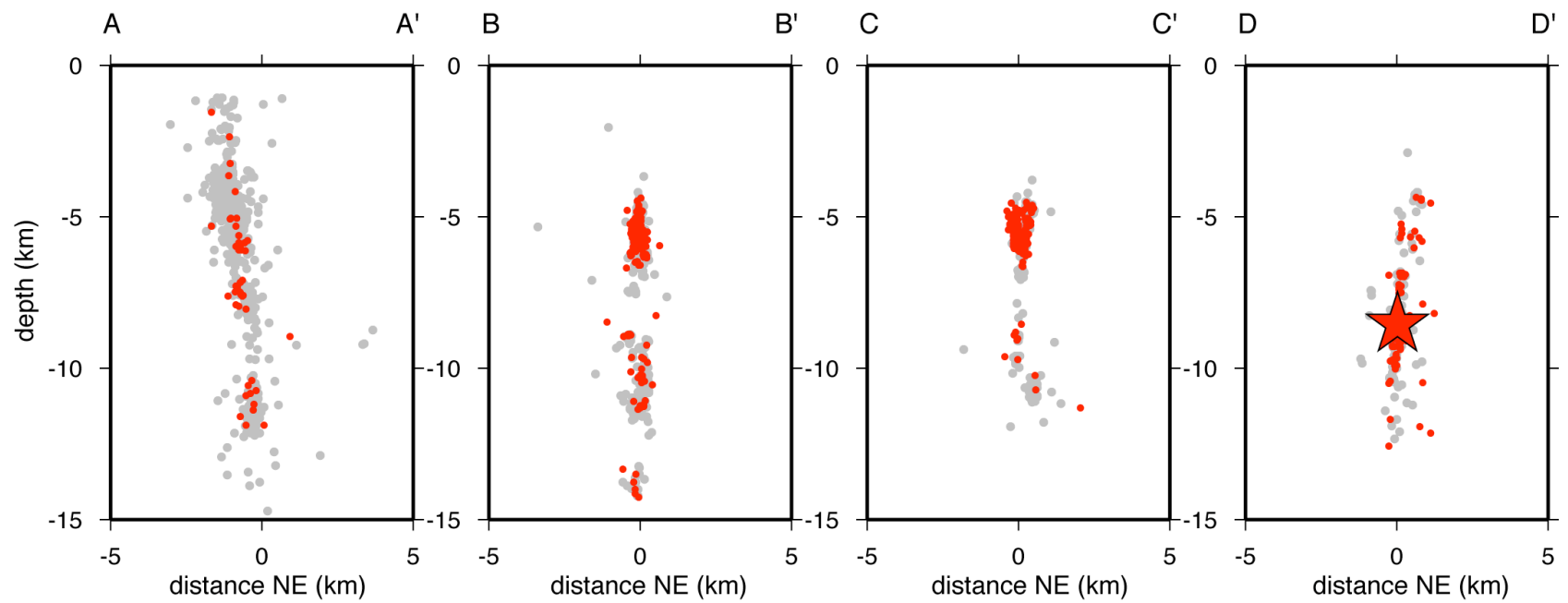
- Network phase picks.
- Absolute locations: using existing Parkfield 3D P-wave velocity model of Michael & Eberhart-Phillips.
- Refine relative locations: using double-difference (Waldhauser & Ellsworth).

## Aftershock relocation relative to background seismicity.

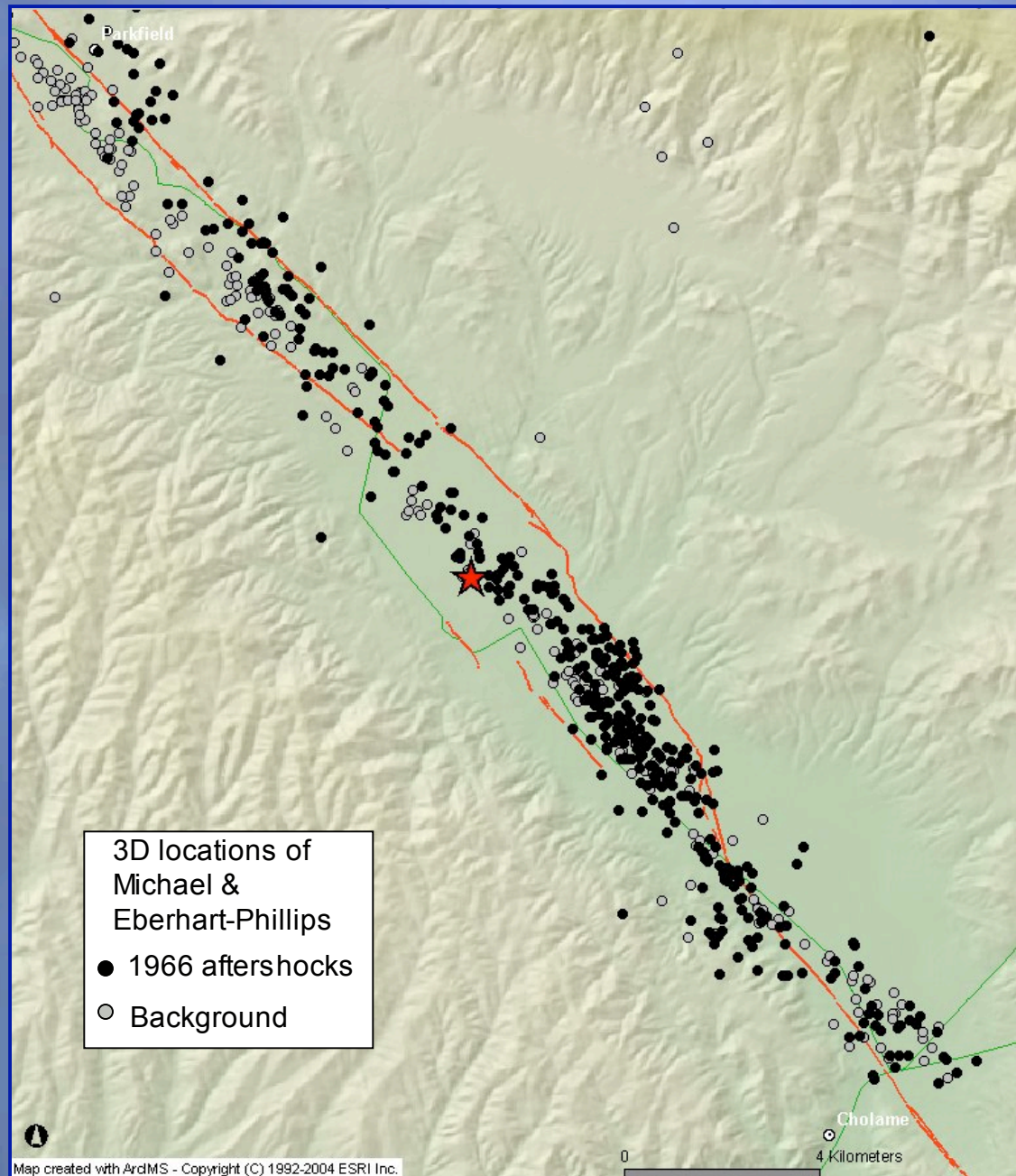
- Double-difference using catalog picks for aftershocks and selected background events 1969-2004.

- Aftershock locations similar to background seismicity.









## What about 1966?

- Difficult to relocate 1966 aftershocks relative to 2004 sequence and background seismicity, because there are only 4 stations linking 1966 aftershocks to the other events.
- Some 1966 portable station sites are being reoccupied, should help.
- Prior work (Michael & Eberhart-Phillips) using 3D velocity model indicates that 1966 aftershocks are spatially similar to background seismicity.

## Conclusions:

- 1) San Simeon mainshock was on a NW-SE striking blind thrust fault.
- 2) The mainshock had significant directivity to the SE, affecting the distribution of shaking and damage.
- 3) The distribution of mainshock slip is fairly simple, with a main slip patch ~15 km SE of hypocenter.
- 4) The aftershocks fill in around the main slip patch.
- 5) The aftershocks near the hypocenter define a NE-dipping fault plane, and a conjugate SW-dipping plane; thrust faulting mechanisms.
- 6) The SE aftershocks are more diffuse; many strike-slip mechanisms.
- 7) Unreinforced masonry buildings performed poorly in the earthquake, retrofit buildings performed well.
- 8) The San Simeon mainshock may have triggered the Parkfield earthquake, raised stress by  $\leq 0.01$  MPa.
- 9) Parkfield aftershocks occur in similar locations to the background seismicity.